FEDERAL AID IN SPORT FISH RESTORATION
Arctic Grayling Culture

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RESEARCH PROJECT SEGMENT

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ABSTRACT

The Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development and Sport Fish Divisions, have coordinated efforts to enhance by artificial propagation the important Arctic grayling, *Thymallus arcticus*, sport fishery within Alaska. All fish culture operations were conducted at Clear Hatchery.

Brood-stock evaluations were conducted on four separate stocks of Arctic grayling: (1) Moose Lake (Copper River drainage) produced 2,258 adults, (2) Jack Lake (Yukon River drainage) 1,760 adults, (3) Goodpaster River (Tanana River drainage) 146 adults, and (4) the experimental hatchery stock (Jack Lake origin) 288 adults. The four sources represented a potential of 12.8 million eggs.

Two separate stocks of Arctic grayling were utilized for egg sources for the production program. Moose Lake was the primary source; it supplied 1,902,400 (90.6%) of the eggs. The Goodpaster River supplied 198,300 (9.4%) eggs.

Over 2.1 million Arctic grayling eggs were incubated, and 829,300 unfed fry were released into 49 lakes and streams state-wide. Approximately 495,800 fry were used in a rearing program, and 129,300 eggs, fry, and fingerlings were sent to other research facilities.

Survival of fry during a 32-day experimental rearing program at a mean temperature of 16.4°C ranged from 44.4% to 70%. Overall survival from fry-to-fingerling stage was 49.5%.

A total of 245,600 Arctic grayling fingerlings ranging in size from 1.5 to 8.1 g was stocked into 32 lakes and rivers state-wide.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, rearing, Moose Lake, Goodpaster River, Jack Lake.

INTRODUCTION

Clear Hatchery is a public facility operated by the Alaska Department of Fish and Game (ADF&G), Fisheries Rehabilitation, Enhancement and Development (FRED) Division; it is located on Clear Air Force Base, approximately 138.4 km south of Fairbanks, Alaska on the Parks Highway (Figure 1).

The ADF&G hatchery production program for Arctic grayling, *Thymallus arcticus*, has existed since 1961. Until 1983 the program consisted of taking eggs from wild spawning stocks, incubating them to the fry stage, and releasing the unfed fry into lake systems. This program had limited success for two reasons: (1) wild Arctic grayling spawning operations are difficult to conduct, resulting in errors and production goals that were rarely achieved; and (2) the survival from the unfed fry stage to the adult stage was very low.

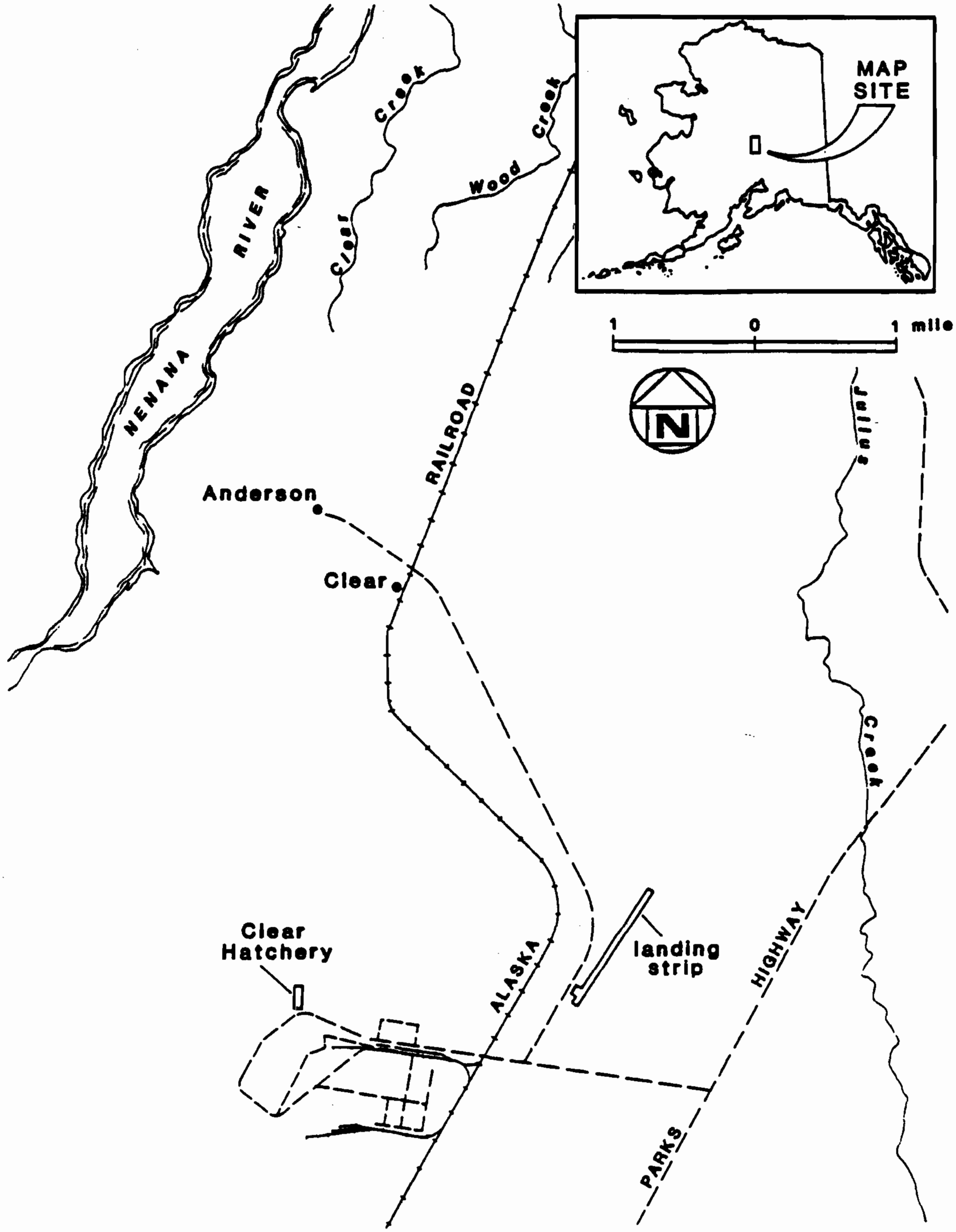

Figure 1. Location of Clear Hatchery.

Fish-cultural procedures were designed to augment survival and reduce competition and cannibalism. Successful culture of Arctic grayling fry depends on (1) the manipulation of the environment to provide adequate water flow to supply oxygen and remove metabolites, (2) suitable water temperatures for growth, and (3) a reliable commercially produced diet. Prior to 1983 all attempts at intensive Arctic grayling culture had been unsuccessful; however, subsequent research has helped to make intensive culture of Arctic grayling feasible. A survival rate of 75% from green-egg to fry is considered achievable.

Since one important constraint limiting the Arctic grayling enhancement program in Alaska is the problem of obtaining sufficient numbers of eggs, new sources must be continually developed. Alternative sources of wild brood-stocks are evaluated in the event that the primary sources fail, but the only viable approach to create a predictably reliable source of eggs is to develop a hatchery brood stock. Considering the logistical constraints and expense of a wild eggtake, it is well worth the effort. Only Lord (1932) has previously reported the establishment of a small hatchery brood stock.

GOALS

The goals of the Arctic grayling program at Clear Hatchery included two components: (1) production of fish for enhancement projects and (2) experimental cultural techniques. We need to develop procedures and procure equipment to produce 200,000 4-g fingerlings at Clear Hatchery with a 75% survival rate; identify and develop alternate wild egg-take sources; and determine the feasibility of developing an Arctic grayling hatchery brood stock and, if feasible, implement that program.

OBJECTIVES

1. Conduct Arctic grayling egg takes at Moose and Jack Lakes (the primary wild brood stocks) to collect 2.0 million eggs.

2. Evaluate adult Arctic grayling brood-stock availability at Goodpaster River, Tahneta Lake, and Butte Lake as alternative brood stocks.

3. Release 200,000 4-g fingerlings in waters selected by Sport Fish Division.

4. Implement the following experimental Arctic grayling cultural techniques:

   a. Evaluate the success of egg incubation and survival to the fry stage in Heath® incubators modified with fine screens.
   b. Conduct loading experiments to determine optimum for survival during incubation.
   c. Conduct rearing experiments to determine optimal conditions for growth and survival of fry fed commercially produced diets.
   d. Rear groups of fry at different loading densities in startup troughs.
   e. Rear experimental lots of fry at different light intensities.
   f. Rear experimental lots of fry at water temperatures between 14°C and 20°C.

5. Rear 450 Arctic grayling to maturity and monitor growth and maturity.

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MATERIALS AND METHODS

Brood-stock Evaluation

Four wild stocks of Arctic grayling were evaluated to determine their run timing, number of available adults, and quality and quantity of eggs: (1) Moose Lake in the Copper River drainage, (2) Jack Lake in the Yukon River drainage, (3) the Goodpaster River in the Tanana River drainage (Figure 2), and (4) the Clear Hatchery experimental brood stock originating from Jack Lake.

Moose Lake adult Arctic grayling were captured in a wooden trap while migrating upstream into Our Creek. Adults were dipnetted from the trap, sorted according to their sex, counted, and placed in net pens to ripen.

Jack Lake adult Arctic grayling were captured in a fyke net while migrating upstream from lower Twin Lake into the outlet of upper Twin Lake. In 1986 adults were separated according to their sex, counted, and released upstream; during the three previous years, captured fish were placed in net pens to ripen and, subsequently, eggs were taken.

Adult Arctic grayling from the Goodpaster River were captured by electro-fishing from a river boat. Adults were separated according to their sex, counted, and placed in net pens to ripen.

The hatchery brood stock was selected on 14 August 1984 from a production lot of Jack Lake fingerlings. Approximately 500 fish were randomly selected and reared in a Heath Techna® circular tank (1.8 x 1 m). These fry were reared at a maximal growth rate using automatic feeders and at maximal water temperatures through 31 October 1985. During mid-September 1985, their diet was changed from OMP-II to BioDiet Brood®. Since 1 November 1985 the photoperiods and water temperature have been controlled to coincide with the natural environment.

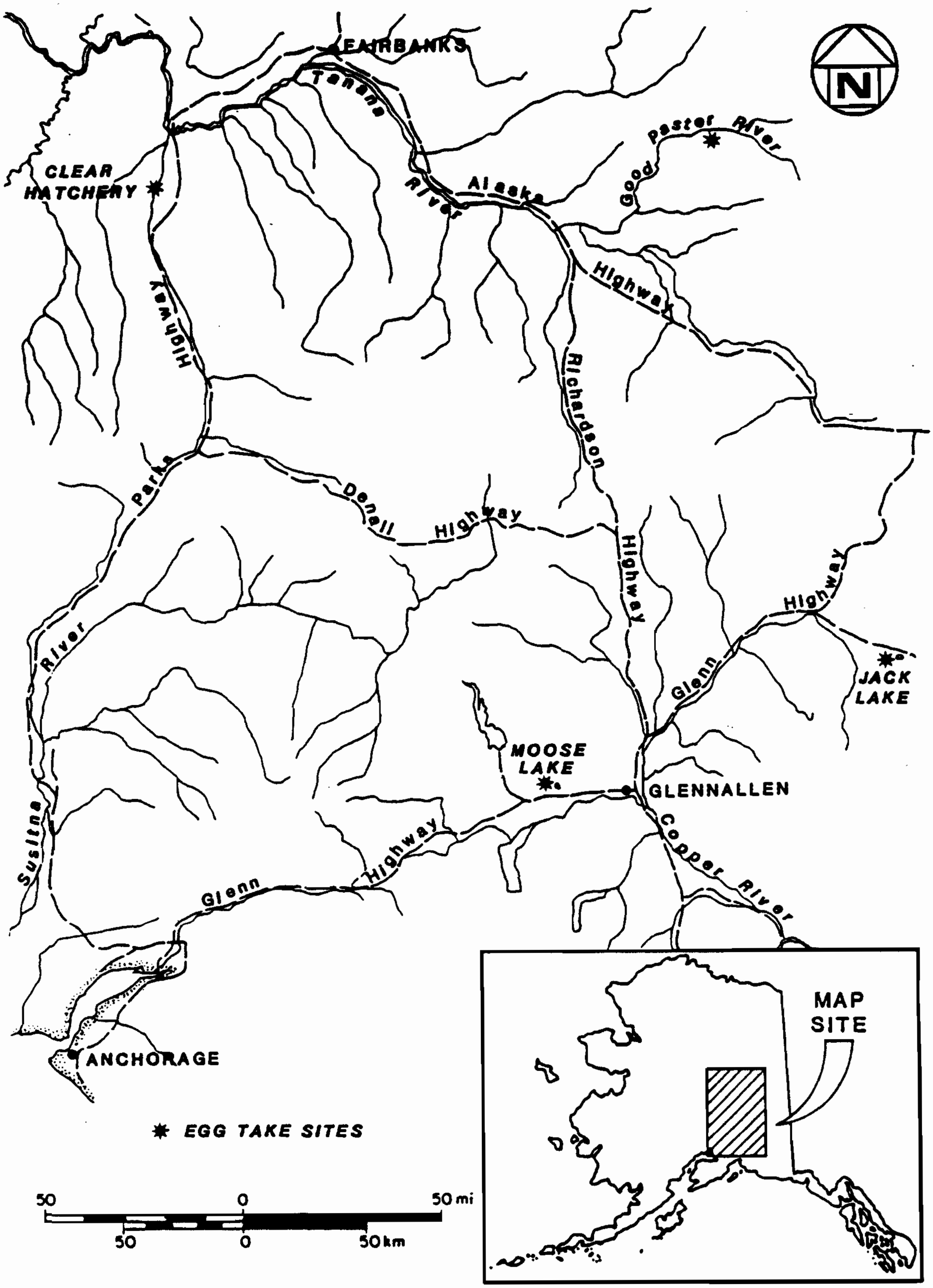

Figure 2. Location of Arctic grayling egg-take sites for Clear Hatchery.

On 8 May 1986 the hatchery brood-stock grayling were anesthetized with MS-222 and checked to determine the presence of eggs and the degree of ripeness. Approximately half of the females and all of the males were marked with a numbered Floy® tag. The total lengths of the fish were measured (mm); and they were weighed (g) and separated into tanks according to their sex. Then the water temperature was raised gradually from 3.7°C to 10°C over an 18-day period.

Egg Take

Prior to spawning, adult males and females from Moose Lake were anesthetized in a CO^2 bath. Adults from the Goodpaster River and the hatchery brood-stock were anesthetized using MS-222. All adults were spawned alive by hand-stripping. Eggs were fertilized and water hardened at the egg-take sites, cooled with lake ice, and transported to the hatchery. The eggs from Moose Lake were transported from the Gakona Airport to the Clear Airport by aircraft; the eggs from the Goodpaster River were hauled by truck directly to the hatchery.

Incubation

All eggs were disinfected for 10 minutes in a Betadine® (100 ppm) bath (Wood 1974) before they were brought into the hatchery. Each stock was totally isolated from the other stocks to minimize the likelihood of disease transmissions. Initially, eggs were incubated in stacked Heath Techna trays having large-mesh (4.7 mesh/cm) screens; 30,600 to 61,200 eggs (i.e., 1 to 2 liters of eggs) were placed in each tray. Prior to hatching, the eggs were transferred to fine-mesh (10.2 mesh/cm) trays. Daily 15-min formalin-drip treatments (1:600) were applied to minimize fungal growth (Wood 1974). Water temperatures (monitored daily) averaged 9.2°C and ranged from 3.5°C to 11.6°C. Water flows were set at 19 liters/min. The developmental rate of some lots of eggs was manipulated to stagger the emergence of fry so that different lots for the feeding experiment could be obtained. After the fry reached the button-up stage, they were transferred to the start-up troughs to be reared or held until release.

An incubator loading experiment was conducted using two stacks of Heath Techna incubators. Each of the top four trays of each stack was loaded with 0.5, 1.0, 1.5, and 2.0 liters of eggs, respectively. Except for the different loading rates, the techniques and culture environment were the same as the production incubation.

Production Rearing

All start-up rearing was conducted in 442- x 54- x 28-cm Heath Techna start-up troughs with a 28-cm standpipe to maintain a usable volume of 660 liters. Approximately 495,800 swimup-stage fry from Moose Lake and the Goodpaster River were held for rearing. Fry from the Moose Lake brood stock were divided into six troughs; four troughs were loaded with 65,459 fry each (0.253 kg/m^3), one trough was loaded with 65,500 fry (0.253 kg/m^3), and one trough was loaded with 50,277 fry (0.194 kg/m^3). The Goodpaster River fry were loaded into 2 troughs at densities of 59,091 each (0.216 kg/m^3).

Each trough was divided into three sections of 220 liters each. Tail and divider screens had 0.5-mm perforations. Fry were initially stocked in the lowest section of each trough; as maximal loading densities were achieved, the next upper divider screen was removed to increase the rearing area.

Initially, water flow was 19 liters/min in each trough, but this was adjusted to maintain a dissolved-oxygen concentration of 8.0 mg/liter. Flows were kept low enough to prevent fry impingement against screens. Dissolved-oxygen concentrations were monitored weekly. Water temperatures were monitored daily; these ranged from 12.2°C to 14.3°C, which was the warmest water available for rearing.

Fry were initially fed "Oregon Moist Pellet II" (OMP) starter mash with a double-vitamin (DV) pack. The DV pack was used to provide extra vitamin C for prevention of scoliosis that had occurred during previous rearing experiments. The OMP-DV was ground with a mortar and pestle and sifted to obtain the required small particle size and to increase acceptability. Feed was dispensed at 10-min intervals on a 24-hours/day basis with Loudon North Star® automatic feeders. Fluorescent lights were installed under the feeder's spread bars along the entire length of the troughs to provide approximately 300 footcandles of light at the water surface for 24 hours/day because other experiments had indicated that Arctic grayling fry are photopositive and congregate in rearing troughs where the desired illumination is present.

Troughs were cleaned and dead fry were enumerated and removed daily. Weights (g) and total lengths (mm) were measured when the fry emerged and every 16 days thereafter until release.

When maximal densities were achieved in the troughs, the fingerlings were transferred into a 17.0- x 2.0- x 0.8-m concrete raceway where they were reared until their release. Fish were fed by automatic feeders every 5 minutes on a 24-hours/day basis.

<u>Experimental Rearing</u>

A rearing experiment was conducted for 32 days using two troughs. Six other troughs were the controls. Approximately 65,500 swimup fry from the Moose Lake brood stock were stocked into one experimental trough and 50,277 fry were stocked into the other. Lack of fry limited an equivalent number in trough 8. Four control troughs were stocked with 65,459 fry each, and two control troughs were stocked with 59,091 fry each.

The mean water temperature was increased from 13.5°C to a maximum of 16.4°C with a 12,000-watt electrical immersion heater. The mean water temperature during the 32-day experiment was 16.4°C. All other techniques and the culture environment were identical to those for the production lots.

Stocking

Fry were transported for stocking by placing a maximum of 30,000 fry and 19 liters of water into each plastic bag; oxygen was added, and the bags were sealed. These were placed into coolers, iced, and transported by plane or truck to various release sites. Most of the unfed fry were planted by Sport Fish Division biologists.

Fingerlings were transported by hatchery personnel in a 1,900-liter fish transport tank to the release site. Tank loadings never exceeded 0.16 kg of fish/liter of water. In all releases, every effort was made to minimize differences in water temperature between the transport tanks and the receiving water.

RESULTS

Brood-stock Evaluation

A total of 12.8 million eggs were potentially available from the four brood stocks between 13 May and 5 June 1986 (Table 1). Among the wild brood-stocks, the lowest number of eggs were available from the Goodpaster River; the highest number of eggs were available from Moose Lake. Brood-stock collection in the Goodpaster River was more time consuming than at the other locations, but approximately 0.5 million eggs were potentially available from the hatchery brood stock of 286 adults, of which 50% were females. This egg take was obviously the most efficient and least time consuming.

Unfortunately, the Arctic grayling brood-stock evaluations at Butte and Tahneta Lakes could not be completed during 1986.

Table 1. Characteristics of Arctic grayling brood stocks, 1986.

Brood-stock	Spawning period	Sex	Numbers of adults Captured		Spawned	Average fecundity	Potential number of eggs
Moose Lake	13 May to	F	1,156	F	281	6,770	7,826,100
	21 May	M	1,102	M	281		
			2,258		562		
Jack Lake	20 May to	F	820	F	0	5,026	4,121,400
	2 June	M	940	M	0		
			1,760				
Goodpaster River	15 May to	F	80	F	42	4,722	377,800
	26 May	M	66	M	30		
			146		72		
Hatchery	23 May to	F	184	F	145	2,648	487,300
	5 June	M	102	M	102		
			286		247	Total	12,812,600

Egg Take

The egg take at Moose Lake was conducted on 21 May. Approximately 1.9 million eggs were taken from 281 females. Average fecundity was 6,770 eggs per female. A male to female ratio of 1:1 was used. The Goodpaster River egg take was held on 19 and 22 May. Approximately 0.2 million eggs were taken from 42 females; the average fecundity was 4,722 eggs/female. Quality and quantity of eggs from both sources were excellent.

All hatchery brood-stock fish matured at 2 years. The average weights and lengths for males and females was 182 g and 25.5 cm and 187 g and 24.5 cm, respectively. Egg takes were conducted on 23 May, 30 May, and 5 June to obtain a total of 487,300 eggs. The average fecundity was 2,648 eggs/female. Eggs were extremely small and averaged 74,781 eggs/liter.

Incubation

The water temperature within the incubators averaged 9.2°C throughout the 19-day incubation period, resulting in an accumulation of 174 temperature units (TU).

Formalin drip treatments were administered every day until the eggs began to hatch. Previously, formalin treatments had been made every other day. It appeared from visual observation that there was less fungal growth during 1986 than usual.

The survival rates for green eggs to fry was 84.8% from the Goodpaster River and 67.4% from Moose Lake; however, one lot of approximately 180,000 eggs from Moose Lake experienced almost 100% mortality. These eggs had been intended for other experiments, and the mortality was possibly due to long-term incubation at low temperature. The survival rate of the eggs from the hatchery brood stock was essentially zero. Mortality of eggs began immediately, and within 10 days almost 100% mortality had occurred.

There were no apparent differences in the egg survival rates between incubator trays loaded at 0.5 to 2.0 liters of eggs (Table 2). Mean mortality rates for each loading density follow: (1) 0.5 liters, 5.1%; (2) 1.0 liters, 6.2%; (3) 1.5 liters, 5.2%; and, (4) 2.0 liters, 4.7%.

Production Rearing

The average survival rate from the fry to fingerling stage was 49.5%: the Moose Lake brood-stock survival rate was 50% and the Goodpaster River survival rate was 48% (Table 3). Growth rate of the fry from the Moose Lake stock was .055 mm/TU/day with a 1.6:1 food conversion. Growth rate of fry from the Goodpaster River was .065 mm/TU/day with a conversion rate of 1.8:1.

Experimental Rearing

The average survival of Arctic grayling reared at elevated temperatures for 32 days was 60.8%; approximately 10 percentage points greater than those in the control lots; (i.e., 20.6% higher survival rate) (Table 4). The net growth of fry was substantially greater at the higher water temperature for both length and weight (Table 5). The growth rate (i.e., average gain/TU/day), however, was similar at both temperatures. Those fish reared at the higher water temperature therefore grew faster.

Stocking

Over 829,300 unfed Arctic grayling fry were stocked into 49 lakes and streams statewide. A total of 245,600 fingerlings ranging from 1.5 to 8.1 g (average weight was 3.5 g) was stocked into 32 lakes and streams. For the most part, transports and stockings went well, except 300 fish were killed when a baffle shifted in a tank and 6,170 fish were killed when an oxygen line became pinched.

Table 2. Mortality of Arctic grayling eggs loaded into incubator trays at different densities, 1986.

Eggs loaded			Egg mortality		
Liters	Number	Replicate	Number	Percentage	Average
0.5	14,600	1	466	3.2	5.1
0.5	14,600	2	1,019	14.3	
1.0	29,200	1	1,246	4.3	6.2
1.0	29,200	2	2,383	8.2	
1.5	43,800	1	2,057	4.7	5.2
1.5	43,800	2	2,532	5.8	
2.0	58,400	1	2,862	4.9	4.7
2.0	58,400	2	2,596	4.4	

Table 3. Arctic grayling survival rates, 1986.

Brood-stock	Number of eggs	Number of emergent fry	Survival (%) from egg to emergent fry	Number: Fry released	Number: Fry reared	Number: Fingerling	Survival (%) from fry to fingerling	Size (g) range of fingerling
Moose Lake	1,902,400	1,282,945	67.4	785,000	377,600	188,827	50.0	1.5 to 6.2
Goodpaster River	198,300	168,182	84.8	50,000	118,182	56,751	48.0	2.1 to 8.1
Hatchery	384,000	0	0	0	0	0	NA	
Total	2,484,700	1,451,127	58.4	835,000	495,782	245,578	49.5	

Table 4. Survival rates of Arctic grayling reared at different water temperatures during a 32-day period, 1986.

Brood-stock	Replicate	Treatment	Water Temperature(°C)	Rearing density Kg/m^3	Rearing density Fry/Liter	Number of fish Start	Number of fish End	Survival rate (%)
Moose Lake	1	Control	13.5	0.253	298	65,459	32,141	49.1
Moose Lake	2	Control	13.5	0.253	298	65,459	34,517	52.7
Moose Lake	3	Control	13.5	0.253	298	65,459	36,154	55.2
Moose Lake	4	Control	13.5	0.253	298	65,459	34,865	53.3
Mean								52.6
Goodpaster River	1	Control	13.5	0.216	269	59,091	26,236	44.4
Goodpaster River	2	Control	13.5	0.216	269	59,091	30,718	52.0
Mean								48.2
Moose Lake	1	Warm Water	16.4	0.253	298	65,500	35,241	53.8
Moose Lake	2	Warm Water	16.4	0.194	228	50,277	35,205	70.0
Mean								61.9

Table 5. Growth of Arctic grayling fry reared at different water temperatures for 32 days, 1986.

Brood-stock	Replicate	Treatment	Water temp. (°C)	Average weight (g)		Average length (mm)			
				Start	End	Start	End	Daily gain	Gain/TU/day
Moose Lake	1	Control	13.5	0.0174	0.376	13.5	35.5	0.69	0.051
Moose Lake	2	Control	13.5	0.0174	0.404	13.5	35.6	0.69	0.051
Moose Lake	3	Control	13.5	0.0174	0.428	13.5	36.4	0.72	0.053
Moose Lake	4	Control	13.5	0.0174	0.407	13.5	37.2	0.74	0.055
Goodpaster River	1	Control	13.5	0.0165	0.487	14.0	40.3	0.82	0.061
Goodpaster River	2	Control	13.5	0.0165	0.472	14.0	39.3	0.79	0.058
Moose Lake	1	Warm Water	16.4	0.0174	0.722	13.5	43.2	0.93	0.057
Moose Lake	2	Warm Water	16.4	0.0174	0.715	13.5	41.9	0.89	0.054

DISCUSSION

Brood-stock Evaluation and Egg Take

Brood-stock investigations during 1986 demonstrated that over 12.4 million Arctic grayling eggs were available from three wild brood stocks. Moose Lake will remain the primary source because of its large adult fish population, early spawning period, and excellent quality and quantity of eggs (Table 1). This site, however, has poor access requiring an approximate 5-km trip by all-terrain vehicle. Jack Lake will be the primary backup source because the run timing is 7 to 10 days later than Moose Lake, the population is large enough to meet the 2 million egg-take goal, and there is an excellent quality and quantity of the eggs. Access to this site is excellent, but the trapping operation is hampered by ice and high water because the Lower Twin Lake breakup occurs during the egg take. An egg take on the Goodpaster River is the most likely to fail because of its inaccessibility and the difficult adult-capture conditions during the breakup period. The adult population size is small, and a potential limit of 400,000 eggs makes this source a poor candidate for a primary egg-take site. Also, since the spawning period of this brood stock is similar to that of Moose Lake, it cannot be used as a backup source. This brood stock is recommended, however, as an alternate egg source for Arctic grayling stocking projects in the Yukon River drainage.

Only minor deviations from the objectives of the brood-stock evaluation plan were made during 1986: (1) One of the primary egg-take sites was changed from Jack Lake to the Goodpaster River; nevertheless, the egg-take goal of 2.0 million eggs was achieved. (2) The planned evaluation of the Butte Lake brood stock did not occur, because breakup was later than usual in 1986 and additional personnel were required to man the primary egg-take sites longer than usual. (3) The Tahneta Lake brood stock had been evaluated during 1984 and 1985, and additional investigation could not be performed during 1986. The spawning period there is comparable to that of Jack Lake, and approximately 600 adults are available for a potential egg take of about 900,000 eggs. This lake is recommended as a secondary brood stock, and it does not require any further evaluation.

After 2 years, a hatchery brood stock has been established from the Jack Lake Arctic grayling population. Warm rearing temperatures for a portion of the brood-stock culture process, however, resulted in a significantly reduced age at first maturity. This probably led to poor survivals for the hatchery brood-stock eggs. There were several important differences between the spawning of the wild Arctic grayling population and the hatchery brood stock. Fish in the wild populations mature at a larger size than those in the hatchery, and they are at least 4 years old when first mature (Williams, pers. comm.). The mean length of the mature hatchery brood-stock fish was 250 mm, which is significantly smaller than the size of fish at first maturity in the Jack Lake population. The average egg size for the hatchery brood stock (74,781 eggs/liter) is substantially smaller than that of the Jack Lake brood stock (26,200 eggs/liter), and the average fecundity (2,648 eggs/female) was less than that of the Jack Lake population (5,026 egg/female).

Gall (1974) reported that the percentage of eggs reaching eyed stage increased as egg size increased in lots of hatchery-reared rainbow trout, *Salmo gairdneri*. In general, larger and older females produce greater numbers of larger eggs than smaller and/or younger individuals (Rounsefell 1957; Buss and McCreary 1960; Gall 1969). The observations that egg size, female size, and fecundity of the hatchery brood-stock were markedly less than the parent population would be consistent with the hypothesis that the lower survival rate resulted from a lower age at maturity.

If the hatchery brood-stock fish grow during the next 2 years, egg size, fecundity, and eyed-egg survival should also increase. If the rate of survival can be significantly increased, the establishment of an Arctic grayling hatchery brood stock from a natural stock will be truly beneficial.

Incubation

The success of hatchery production programs begins with the acquisition of a suitable quality brood-stock and sufficient egg production. Then maximal benefit can be derived from good egg and fry survivals. The poor survival of the eggs taken from the hatchery brood stock in 1986 was attributed to the unusually small size of the eggs that apparently resulted from the early maturation of the brood stock. The survival of Arctic grayling eggs are also affected by their adhesiveness, which may result in clumping and/or fungal infections. When fry are allowed to volitionally emerge through a stack of Heath incubator trays with large-mesh screens, they collect at tray bottoms or drain plugs and suffocate. Two incubation techniques to increase egg and fry survival that are now incorporated into our standard operating procedures are (1) daily formalin drip treatments and (2) hatching in fine-mesh screened trays. The formalin drip helps to minimize fungal infections, the fine-mesh screened trays trap the fry in the tray, and adequate water flows eliminate suffocation. Fry are confined to the trays until most of their yolk sac is absorbed and are ready to swim-up. Unfortunately, air may be trapped and bubbles may form underneath the bottom screen; however, if the stack is tilted forward by adjusting the leveling screws, the bubbles are dissipated towards the back of the tray. With these strategies, we expect the survival of emergent fry to average at least 85% next year.

Production and Experimental Rearing

Some of the most important factors affecting fry survival in the hatchery include the water temperature, diet, timing of feeding, food density, fish density, and light intensity. Arctic grayling fry stocked at a density of 0.194 kg/m^3 and reared in 18°C water survived better (70%) than those stocked at higher densities and lower water temperatures. Growth was significantly greater for fish reared at 16.4°C than 13.5°C.

Arctic grayling fry are positively phototactic, and they move to areas of troughs where the preferred illumination is present. If lighting for newly ponded fry is inadequate, the fry tend to settle on the bottom until crowding causes suffocation. Although we did not conducted experiments to compare different levels of light intensity, our lighting condition of 300 footcandles appears to have been adequate.

Two causes of mortality during rearing were starvation and scoliosis caused by a vitamin C deficiency. During the first 10 days, approximately 40% of the mortality was attributed to starvation. The nutritional requirements of Arctic grayling, like those of many other coldwater fishes, are poorly known. Those fry that start feeding, however, appear to eat and grow well (at least through the fingerling stage) on the high protein diet OMP-DV. Early adaptation to this diet is essential to reduce starvation during the prefingerling stage of intensive culture. It appears that Arctic grayling fry will die if they do not start feeding within the first 7 to 10 days at 13.5°C. At higher water temperatures, they will die even sooner. Fry should be ponded as soon as they are able to swim to the surface. Since the first 10 days after hatching are the most critical, food should be fed in excess at least once every 10 minutes for 24 hours/day.

The quality of the feed is as important as the quantity of the feed. Fry mortality from scoliosis was estimated at only 2% to

5% in 1986. Results from previous diet experiments suggested that scoliosis can be reduced or eliminated if extra vitamin C is added to their diet. Apparently, grinding and sieving the OMP-DV to a smaller size reduces the vitamin C content, and Arctic grayling fry require higher levels of vitamin C than other salmonid fry. The standard OMP diet contains a concentration of Vitamin C of approximately 893 mg/kg. The OMP-DV has twice that amount with 1,786 mg/kg. In an attempt to control scoliosis even better next year, fry in production lots will be fed OMP-DV having a vitamin C concentration of approximately 3,200 mg/kg.

Overall, Arctic grayling fingerling production and survival exceeded the original objectives. Sport Fish Division originally requested approximately 200,000 fingerlings for stocking; the actual production of 245,600 fingerlings was nearly 25% greater than that request. The expected survival rate was 25%; the actual one was twice that at 49.5%. All fingerlings, including the surplus, were stocked into 32 lakes and rivers statewide, which is a new hatchery and department record for Arctic grayling.

The average size of fingerlings when released was similar to the desired average size. The wide range in the average size, however, was achieved to accommodate experiments designed by Sport Fish Division personnel to assess the survival rates of different sized fingerlings.

CONCLUSIONS

A total of 2.1 million Arctic grayling eggs was taken from fish at Moose Lake and the Goodpaster River in 1986. The Jack Lake brood stock will be the primary backup egg-take site if the Moose Lake egg take failed; the Tahneta Lake brood-stock will be the secondary backup location. A total of 245,600 fingerlings between 1.5 and 8.1 g was released into 32 lakes and streams.

Experimental Arctic grayling cultural techniques were successful. Arctic grayling eggs should be loaded into incubator trays at a rate of 1-2 liters of eggs per tray. Arctic grayling eggs should be incubated in trays with large-mesh screens, but these should be transferred to trays with fine-mesh screens before hatching. Rearing density should be 200 fry/liter, and light intensities should be 300 footcandles evenly distributed for 24 hours/day; and the greatest growth of Arctic grayling fingerlings occurred at 16.4°C. Good growth of Arctic grayling fry can be achieved with finely- ground Oregon Moist Pellet II starter mash with a double vitamin pack and fed at 10-minute intervals for 24 hours/day.

A total of 286 Arctic grayling matured in 1986 and a total of 384,000 eggs was obtained. The hatchery brood-stock fish grew faster, matured at a smaller size, and, matured 2 years sooner than fish from wild brood stocks. The average size of the eggs from the hatchery brood stock, however, was approximately one-third that of the wild brood stocks.

RECOMMENDATIONS

Brood-stock Evaluation

1. Continue to grow the 1984 hatchery brood stock at the maximal rate by adjusting the water temperature and photoperiod according to their natural environment. Increased adult size should produce a higher fecundity, larger eggs, and an acceptable survival rate (60%).

2. Randomly select 2,000 Moose Lake Arctic grayling (1986 brood) for additional experimental brood stock.

Egg Take

1. Continue to use Moose Lake as the primary brood stock for spawning operations.

2. Use Goodpaster River brood stock for Yukon River drainage enhancement projects.

3. Use Jack Lake and Tahneta Lake brood stocks as primary backups.

4. Calculate the egg-take goal with planning assumptions of 75% egg-to-fry and 50% fry-to-fingerling survival rates.

Incubation

1. Load incubators with a density of 1-2 liter of eggs per tray.

2. Treat the eggs daily with formalin.

3. Incubate eggs in trays with large-mesh screens, but before hatching transfer them to fine-mesh screened trays.

Rearing

1. Initial rearing density should be 200 fish/liter.

2. Feed OMP-DV with 3,200 mg vitamin C/kg every 10 minutes for 24 hours/day.

3. Provide even lighting conditions over the entire trough at approximately 300 footcandlesfor 24 hours/day at water surface.

4. Rear all production lot fish at water temperatures of 18°C.

5. Conduct rearing experiments using different levels of light intensity.

6. Release 200,000 4.0-g fingerlings.

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